Current trends in endodontic irrigation amongst general dental practitioners and dental schools within the United Kingdom and Ireland

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Current trends in endodontic irrigation amongst general dental practitioners and dental schools within the United Kingdom and Ireland: a cross-sectional survey

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Key Words

Apical Periodontitis

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Irrigation

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Survey

Cover Letter

On behalf of the co-authors and I, we would like to submit this manuscript for consideration for publication in the Research Section of the British Dental Journal.

We feel it will be of interest to the readership of the BDJ on an international setting as it will provide information on the current teaching practices, with respect to endodontic irrigation, amongst the dental schools within the UK and Ireland.

Furthermore, we feel this information will be of interest to the readership of the BDJ as it also provides information on the current irrigant practices of GDPs across the UK. The results shine a positive light on GDPs which we feel is important to highlight, particularly in light of recent BDJ papers such as Oxley et al 2017; 222: 391 – 395. The manuscript can also be used by GDPs as an educational tool as it provides them information directly conveyed by the endodontic course leads from all 18 dental schools within the UK and Ireland.

Yours Sincerely,

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In Brief / Key Points

- Provides information of the current undergraduate teaching practices, in relation to endodontic irrigation, within UK and Ireland Dental Schools

- Described the current trends in endodontic irrigation amongst NHS and private general dental practitioners within the UK

- Discusses the changes in teaching and usage of endodontic irrigants over the last two decades.

Abstract

Aims: To investigate current trends in endodontic irrigation amongst general dental practitioners (GDPs) and dental schools within UK and Ireland. Secondly, evaluate if

significant differences exist between the irrigant practices of National Health Service (NHS) and private GDPs.

Methodology: In 2019, an online questionnaire was distributed to the 18 dental schools within the UK and Ireland and 8,568 GDPs. These surveys explored current trends in teaching and usage of endodontic irrigants. Chi-squared tests were performed to make comparisons between NHS and private GDPs ($\alpha<0.01$).

Results: All 18 dental schools (100%) and 495 GDPs (6%) returned valid questionnaires. Three-hundred-and-thirty (66.7%) practitioners were NHS and 165 (33.3%) private. There was strong concensus on irrigation teaching amongst dental schools. These results aligned with GDP responses in terms of irrigant selection (Sodium Hypochlorite [NaOCl]); NaOCl concentration (≤3%); ethylenediaminetetraacetic acid (EDTA) contact-time (>0–5m), final rinse protocols (penultimate EDTA rinse); irrigant temperature (room) and agitation techniques (manual dynamic activation; >0–60s). There was however considerable variation in NaOCl contact-time and GDPs infrequently used chelating agents or agitation techniques. Compared with private practitioners, NHS GDPs used significantly lower NaOCl contact-times and concentrations, less EDTA and activation techniques, and more chlorhexidine ($P<0.01$).

Conclusions: Overall, irrigation teaching within the UK and Ireland is consistent and evidence-based. Furthermore, trends in irrigant usage amongst UK GDPs are now more aligned with these teaching practices. Significant differences were however observed between NHS and private practitioners.

Introduction

Apical periodontitis is an inflammatory condition initiated by pathogenic micro-organisms residing within infected root canals.[1] Current treatment strategies focus on reducing the endodontic bacterial load to levels that are compatible with periradicular healing.[2] This is clinically achieved through a process of chemomechanical disinfection, whereby hand or rotary instruments widen the root canal to facilitate deeper penetration of anti-bacterial solutions.[3] Emphasis is placed

on the latter irrigation component as a significant portion of the root canal surface can remain uninstrumented following mechanical preparation.[4,5]

As the majority of endodontic treatment is performed by general dental practitioners (GDPs) in primary care, it is important to update our knowledge of how this cohort of dentists chemically disinfects root canals. The last studies on irrigant practices within the United Kingdom (UK) were conducted over 10 years ago.[6,7,8] At that time, considerable variation in irrigant selection was reported amongst GDPs who worked predominately in the National Health Service (NHS), with local anaesthetic solution being a popular choice. This contrasts the irrigant practices of dentists in Australia[9], USA[10], Turkey[11] and India[12], where over 90% reported to use sodium hypochlorite (NaOCl). No follow up investigations have since been conducted and none that examine clinical trends beyond simply the choice of irrigant solution. Moreover, the NHS has undergone significant reform and a considerable amount of research on chemical disinfection has been disseminated during this period.[13,14,15] Whether these factors have had any impact on clinical behaviours of primary care practitioners in the UK, with respect to root canal irrigation, currently remains unknown.

One potential explanation for the aforementioned international discrepancies is differences in the irrigation protocols taught at dental schools within and immediately local to the UK (i.e. Ireland). Current perceptions amongst experienced UK dentists are that graduates from these institutes enter into dental practice with unsatisfactory endodontic knowledge and skills.[15] It would therefore be of use to also ascertain how the undergraduate curriculum across this region prepares students for general dental practice in relation to root canal irrigation. Once again, previous dental school surveys have only reported on the type of solution advocated and not any other

parameter that could potentially enhance the efficacy of irrigants within root canals.[16,17]

The primary aim of this cross-sectional survey was to investigate the current trends in endodontic irrigation amongst GDPs and dental schools within UK and Ireland. Secondly, this study explored if there were any significant differences in the irrigant practices between NHS and private GDPs. The tested null hypothesis was there were no significant differences between these two GDP cohorts.

Methodology

Questionnaire Design

Following full ethical approval from the University of Birmingham's Research Ethics Committee (Ref: ERN_19-0854), two anonymised questionnaires were designed using the Bristol Online Survey tool (Bristol Online Survey, Bristol, UK). The questionnaire sent to endodontic teaching leads (i.e. dental school survey) consisted of 10 questions investigating various aspects of irrigant teaching within the 18 UK and Ireland dental schools with an undergraduate training programme (Supplementary 1). The questionnaire sent to primary care practitioners (i.e. GDP survey) consisted of 5 initial demographic questions and a further 10 questions relating to the trends in irrigant usage amongst UK GDPs (Supplementary 2). Questions were either open or closed, with some allowing multiple answers, and space was provided after each closed question for respondents to make additional comments in the event their usual practice was not adequately represented by the available choices. Questions were then independently reviewed by a subject matter (PLT) and survey design (VR) expert to confirm they captured the relevant

information without being leading or ambiguous. Thereafter, both surveys were piloted by GDP tutors and clinical lecturers at the University of Birmingham School of Dentistry and revised based on feedback. The final questionnaires were disseminated alongside an explanatory cover letter detailing the aims of the project.

Questionnaire Distribution

The dental school questionnaire was emailed to the endodontic teaching leads in all UK and Ireland dental schools via the "British Endodontic Society Teachers in Endodontology" group. Three follow-up emails were sent to non-respondent staff members at one-month intervals after which they were contacted via telephone.

The GDP questionnaire was posted online to 8,568 GDP members of the private social media group "The Dentist UK" (URL: https://www.facebook.com/groups/738281152968425/), which explicitly required verification of GDC registration prior to membership and participation. This web-based/online survey was re-advertised to practitioners within the forum on three occasions at one-month intervals. To reduce the risk of double responses, the cover letter explicitly invited only those GDPs working in primary care who had not already taken part in the survey. To ensure the results accurately reflected the irrigant practices of this cohort, a sample size calculation was conducted using an online sample size tool (Roasoft Inc, Washington, USA). Based on the latest data from the Office of National Statistics, there are currently 25,000 self-employed dental practitioners working across the UK.[18] As no prior data exists on many of the questions asked within this survey, an expected outcome of 50% was assumed. Thus to achieve a confidence level of 95%, with a 5% error margin, a minimum of 379 GDP responses were required.

Both surveys were opened from 1st August 2019 to 31st December 2019. Respondents from either group did not receive any incentive to participate and were under no obligation to respond, consent was simply implied by completion and submission of the questionnaire. Only those responses where all questioners were answered were considered valid and included in the subsequent analysis. In the GDP survey, practitioners were categorised into those who worked predominately (> 50%) in an NHS or private setting.

Statistical Analyses

Descriptive statistics (*n*; %) were used to describe trends in endodontic irrigation and chi-squared tests performed with SPSS V.25 software (IBM, New York, USA) to make comparisons between NHS and private GDPs. After Bonferonni correction, the alpha value considered statistically significant for all tests was 0.01.

Results

Response Rate

All 18 dental schools provided a valid response and 503 GDPs returned questionnaires of which 495 were appropriately completed. This gave an overall response rate of 100% and 6%, respectively.

Demographic Characteristics of GDP Respondents

The demographic characteristics of GDP respondents are summarised in Table 1. Overall, 424 (85.7%) practitioners attained their primary dental qualification from a UK or Ireland tertiary education institute, with 71 (14.3%) qualifying overseas. Whilst the majority of respondents graduated from the University of Liverpool (56; 11.3%), all dental schools were represented. The greatest proportion of respondents had been practicing in the UK for 1 – 10 years (241; 48.7%) and the least for 31 – 40 years (5; 1.0%). England was the most represented region (418; 85%) followed by Scotland (40; 8.1%), Wales (25; 5.1%) and Northern Ireland (12; 2.4%). Three-hundred-and-thirty (66.7%) practitioners declared themselves predominately NHS and 165 (33.3%) private. Similar demographic characteristics were present when these two GDP groups were analysed independently.

Irrigant Solution Usage

Trends in irrigant selection are summarised in Table 2. All 18 dental schools teach their undergraduates to use NaOCl during root canal treatment, with 3 (17.0%) advocating its use to the exclusion of other irrigant solutions. The remaining 15 (83.0%) institutes teach NaOCl irrigation alongside a chelating agent, such as ethylenediaminetetraacetic acid (EDTA; 13; 72.2%) or citric acid (2; 11.1%). Relatively few teaching institutes encouraged the use of chlorhexidine (3; 16.7%), iodine (1; 5.6%) and saline (1; 5.6%).

Amongst all GDP respondents, the most widely selected irrigant was NaOCl (464; 93.7%) followed by EDTA (281; 56.8%), chlorhexidine (113; 23.0%), local anaesthetic solution (45; 9.1%) and saline (32; 6.5%). Other less frequently used irrigants included citric acid, hydrogen peroxide, hypochlorous acid, iodine, dual rinse HEDP, isopropyl alcohol and succinic acid. One-hundred-and-twenty-nine (26.1%) respondents reported using only NaOCl during root canal treatment and 282 (60.0%)

used it in conjunction with a chelating agent such as EDTA (278; 56.2%) and/or citric acid (8; 1.6%). Private GDPs reported more frequently using EDTA, and less frequently using chlorhexidine, when compared with NHS counterparts ($P < 0.001$).

The majority of practitioners who abstained from using NaOCl (31; 6.3%) stated they opted for alternative solutions, namely chlorhexidine, as a way of avoiding hypochlorite accidents (12; 2.4%). A smaller proportion (3; 0.6%) reported they did not have access to NaOCl in their practice and the remaining 16 GDPs offered no explanation. From the 45 (9.1%) respondents who used local anaesthetic solution, of which three (0.6%) reported it as being their sole irrigant, only 17 provided a reason for its use. These included aiding analgesia (6; 1.2%) and haemostasis (3; 0.6%), practice accessibility (3; 0.6%), avoiding hypochlorite accidents (2; 0.4%), solution sterility (2; 0.4%) and ease of needle manipulation when access to the tooth was limited (1; 0.2%).

Sodium Hypochlorite Irrigation

Trends in the teaching and use of NaOCl are summarised in Table 3. Overall, the NaOCl concentration most frequently advocated by dental schools was > 2 – 3% (8; 44.4%). This was followed by > 1 – 2% (7; 38.9%) and then > 0.5 – 1% (3; 16.7%). No institute supported the use of NaOCl solutions greater than 3%. Of those GDPs who routinely used NaOCl, the most frequently selected concentration was also > 2 – 3% (196; 39.6%) and the least > 5 – 6% (31; 6.3%), the latter of which was significantly more popular amongst private practitioners ($P < 0.01$). Concerningly, a small proportion of this GDP cohort (11; 2.2%) stated they were administering this irrigant at an unknown concentration.

A small group of dental schools (7; 38.9%) did not teach a specific time-frame for NaOCl exposure but instead, encouraged its use throughout the duration of the treatment. The remaining institutes were considerably varied in their responses as were GDPs. Nevertheless, > 5 - 10 minutes (92; 18.5%) was the most reported contact-time amongst practitioners followed closely by > 0 - 5 minutes (83; 16.7%). Private GDPs however were found to use NaOCl for a significantly longer period of time (> 35 – 40 minutes) than NHS respondents ($P < 0.0001$).

Ethylenediaminetetraacetic Acid Irrigation

Trends in the teaching and use of EDTA are summarised in Table 4. Briefly, the majority of dental schools advocated > 0 – 5 minutes exposure during root canal treatment (22; 66.7%). Two (11.1%) institutes taught > 5 – 10 minutes contact however, time-periods greater than this were not supported by teaching in any dental school. Similarly, most GDPs reported using EDTA for > 0 – 5 (197; 39.9%) and > 5 – 10 minutes (51; 10.3%). Most dental schools (10; 55.6%) and GDPs (225; 45.5%) use EDTA as a penultimate rinse to NaOCl during root canal treatment opposed to a final rinse.

Irrigant Temperature

There was almost universal alignment between dental school (17; 94.4%) and GDP respondents (477; 96.4%), both NHS and private ($P > 0.01$), in that they did not advocate or heat irrigant solutions during root canal treatment.

Irrigant Agitation

Trends in the teaching and use of irrigant agitation techniques are summarised in Table 5. Overall, Manual dynamic activation was the most widely advocated irrigant

agitation method amongst dental schools (13; 72.2%) and was occasionally taught alongside passive ultrasonic and sonic irrigation techniques (3; 16.7%). Similarly, manual dynamic activation was highly popular amongst practitioners (222; 44.8%), followed by passive ultrasonic (99; 20.0%) and sonic irrigation (36; 7.3), the latter of which was used significantly more by private practitioners ($P < 0.01$). Apical negative pressure systems (9; 1.8%) and canal brushes (1; 0.2%) were also utilised in primary care but to a much lesser degree and were not taught by any institute. Interestingly, 61 (12.3%) practitioners reported the use of a combination of manual and machine assisted techniques per canal. Five dental schools (27.8%) and 199 (40.2%) GDPs however declared that they did not teach or use any irrigant agitation technique. The latter cohort consisted of significantly more NHS practitioners ($P < 0.001$).

Most dental schools that taught irrigant agitation techniques advocated durations of > 0 – 30 (5; 27.8%) and > 30 – 60 seconds (4; 22.2%) per canal. A much smaller proportion of institutes opted for more extended time periods such as > 60 – 90 and > 150 – 180 seconds (2; 11.1%). Similarly, the majority of practitioners who agitated irrigants did so for > 0 – 30 (110; 22.2%) and > 30 – 60 seconds (105; 21.2%). No significant differences were found between NHS and private GDPs ($P > 0.01$).

Discussion

Overall, the results of this study indicate that the teaching practices for irrigant use within UK and Ireland dental schools are consistent and evidence-based. Furthermore, trends in endodontic irrigation usage amongst UK GDPs are now more aligned with these teaching practices. Significant differences were however identified between NHS and private practitioners and so the null hypothesis has been rejected.

Valid questionnaire responses were received from the endodontic course leads of every dental school approached to take part in this survey. Thus, the information presented from this portion of the study provides a comprehensive, accurate and representative overview of current undergraduate teaching across the UK and Ireland. For the GDP survey however, the methods used to achieve high response rates in previous investigations (i.e. General Dental Council and Deanery registers) were extensively explored, but unable to be reproduced due to the implementation of General Data Protection Regulations.[6,7,8] Therefore, an online/web-based questionnaire survey design was instead selected due to its ethical fidelity. It is acknowledged however that this method carries with it limitations that may affect the ability of the findings to be representative of the entire UK GDP population. This is principally due to the fact that practitioners who had no internet access or were non-members of the forum could not participate. This is further compounded by a low GDP response rate and that the majority of respondents in this study worked in England. Nevertheless, the minimum target determined by the sample size calculation was still superseded and a broad range of age groups, practice types and dental school backgrounds were captured than ever before. Therefore, whilst caution must be taken when extrapolating results of the present GDP survey to all UK practitioners, they could still provide valuable information to interested dental clinicians, educators, researchers and third party funders.

This study demonstrated NaOCl is still advocated as the irrigant of choice by dental schools within the UK and Ireland. However, unlike previous surveys, it is now often taught to be used alongside a chelating agent such as EDTA. The rationale provided for this combination is consistent with the latest European Society of Endodontology (ESE) Undergraduate Curriculum Guidelines, in that it maximises root canal

disinfection by eliminating “micro-organisms, organic tissue and inorganic material” from within infected root canals.[19] The GDP questionnaire also revealed NaOCl as being the most highly administered irrigant amongst NHS and private practitioners. Where previous investigations in the UK reported 19 – 75% use of this solution, results comparable to international studies were for the first time found in this survey.[6,7,8] This dramatic shift away from the use of local anaesthetic solutions (i.e. from 63% to 9%) and toward NaOCl (i.e. from 19% to 94%) over the last 20 years demonstrates that fewer dentists are deviating from the irrigant practices taught to them during their undergraduate training. Whilst EDTA was the second most popular irrigant solution, it was only used by approximately half of GDP respondents and was strongly associated with private dentists. This alludes to there being financial barriers to the more widespread usage of this solution however; variation in undergraduate learning experience could also play a role as several institutes do not include this irrigant as part of their curriculum. The usage of chlorhexidine on the other hand has remained relatively stable amongst approximately a quarter of GDP respondents and several dental institutes.[8] This outcome is despite emerging evidence highlighting its negative effects on periradicular healing and increased incidents of anaphylaxis.[20,21,22] Frequent reasons cited for its use were not related to its substantive antiseptic activity, but instead to eliminate the risks of hypochlorite injury and more concerningly, when rubber dam was not applied.

In contrast to American practitioners, the current opinion amongst UK GDPs and dental schools favours the use of more diluted NaOCl solutions (≤ 3%).[10] This is likely due to this irrigant demonstrating similar anti-microbial and tissue-dissolving properties to its higher strength counterparts, whilst also exhibiting lower periradicular cytotoxicity.[23,24,25] Consequentially, regular replenishing and more

contact-time would be required as the active chlorine ions that contribute to the NaOCl mechanism of action are spent more rapidly in less concentrated solutions.[26] However, there is currently a lack of evidence-based guidelines on the minimum duration of NaOCl exposure needed for adequate disinfection of root canals. This could explain the considerable variation reported by both GDP and dental school respondents. Of note, less contact time was highly associated with NHS practitioners and longer durations with private GDPs, a finding that further strengthens the association between methods of remuneration and practicing behaviours.[27] Nevertheless, there is an emerging trend amidst a smaller group of endodontic educators within this study that NaOCl use should span the entire length of the root canal procedure. This was explicitly stated in the additional comments section by those dental school respondents who selected “other” for this question (7; 38.9%). Unfortunately, such a notion was acknowledged by only 7 (1.4%) practitioners, which highlights the need for greater clarification in this area.

When EDTA was administered into root canals, educators and practitioners almost always reported it to be used in conjunction with NaOCl for periods of up to 5 minutes as a penultimate rinse. This strong concensus could be explained by the fact that both groups cited its use as being solely for removing smear layer. For this purpose, the reported contact time is consistent with the conclusions of several *in vitro* investigations that sought to determine the minimum duration of EDTA exposure needed to achieve this goal.[28,29] However, a final rinse with NaOCl has long been associated with excessive erosion of peri- and inter-tubular dentine;[30,31] a phenomenon proposed but not proven to render endodontically treated teeth more prone to vertical root fracture.[32] Nevertheless, the continued practice of the reported irrigation sequence would suggest that for dental school and GDP respondents in

this survey, the additional disinfection attained by a final NaOCl rinse outweighs these theoretical risks.

In this study, only two-thirds of dental schools and GDP respondents advocated or used irrigant agitation techniques during root canal treatment. The most favoured method amongst both groups was manual dynamic activation for periods of up to 60 seconds per canal. This trend could be attributed to the relatively inexpensive and simple nature of this technique which makes it widely accessible and easy to teach irrespective of experience level. Furthermore, *in vitro* investigations have demonstrated it as being an effective mechanism for eliminating smear layer and dentinal debris from within all regions of the root canal in addition to promoting deeper tubular penetration of irrigants.[33,34] Machine assisted devices however were used much less but by a higher proportion of predominately private GDPs, particularly sonic agitation. This once again highlights the financial barriers associated with their use, which would disproportionately affect NHS practitioners as the appropriate incentive structures are currently not in place.[27,35,36] Another possible explanation for the sparse use of these devises is that they have yet to demonstrate any clinical effectiveness, with respect to periapical bony healing.[37,38]

Conclusion

Within the limitations of this study, the following conclusions can be drawn:

1. The teaching practices for irrigant use within the UK and Ireland are consistent and evidence-based. However, greater concensus is needed for NaOCl contact-time and additional teaching is required on machine assisted agitation techniques.

2. Current trends in endodontic irrigation amongst UK GDPs are now more aligned to the aforementioned teaching practices. These include irrigant selection (NaOCl); NaOCl concentration (≤ 3%); EDTA contact time (> 0 – 5 min), final rinse protocols (penultimate EDTA rinse); irrigant temperature (room) and agitation technique (manual dynamic activation; > 0 – 60 seconds). Once again, there is considerable variation in NaOCl contact-time and contrary to contemporary teaching practices, practitioners do not routinely use chelating agents or agitation techniques.

3. There are significant differences between the irrigant practices of NHS and private GDPs. NHS practitioners use significantly lower contact-times and concentrations for NaOCl, less frequently use EDTA and agitation techniques and more regularly administer chlorhexidine than private GDPs.

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Conflicts of Interest

The authors explicitly declare no conflicts of interest.

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Table Legends

Table 1: Demographic characteristics of general dental practitioners (GDP) respondents.

Table 2: Trends in endodontic irrigant solution usage for primary root canal treatment (multiple response questions).

Table 3: Trends in sodium hypochlorite (NaOCl) concentration and contact time usage for primary root canal treatment.

Table 4: Trends in ethylenediaminetetraacetic acid (EDTA) contact time and final rinse protocols usage for primary root canal treatment.

Table 5: Trends in irrigant agitation for primary root canal treatment (multiple responses were allowed for the various techniques).

Supplementary Material Legends

Supplementary 1: Sample questionnaire distributed to endodontic course leads in UK & Ireland dental schools

Supplementary 2: Sample questionnaire distributed to GDPs in the UK

Table 1: Demographic characteristics of general dental practitioners (GDP) respondents

Characteristics	Percentage Response (*n*)		
	GDPs (495)	**NHS (330)**	**Private (165)**
Graduated from UK/Ireland			
Yes	85.7 (424)	85.7 (283)	85.5 (141)
No	14.3 (71)	14.3 (47)	14.5 (24)
Years practiced in UK			
1 – 10	48.7 (241)	55.8 (184)	34.5 (57)
11 – 20	26.3 (130)	25.7(85)	27.3 (45)
21 – 30	15.3 (76)	10.6 (35)	24.9 (41)
31 – 40	8.7 (43)	6.7 (22)	12.7 (21)
41 – 50	1.0 (5)	1.2 (4)	0.6 (1)
Region of practice			
England	84.4 (418)	82.4 (272)	88.5 (146)
Scotland	8.1 (40)	10.9 (36)	2.4 (4)
Wales	5.1 (25)	4.6 (15)	6.1 (10)
Northern Ireland	2.4 (12)	2.1 (7)	3.0 (5)
Proportion of private practice			
0% – 50%	66.7 (330)	66.7 (330)	-
51 – 100%	33.3 (165)	-	33.3 (165)

The figures in parenthesis represent the total number of respondents

Table 2: Trends in endodontic irrigant solution usage for primary root canal treatment (multiple response questions).

Irrigant Solutions	Percentage Response (*n*)				
	Schools (18)	GDP (495)	NHS (330)	Private (165)	*P* [a]
Chlorhexidine	17.0 (3)	23.0 (113)	27.0 (90)	14.0 (23)	< 0.001
Citric Acid	11.0 (2)	1.6 (8)	1.2 (4)	2.4 (4)	*NS*
Dual Rinse HEDP	-	0.2 (1)	-	0.6 (1)	*NS*
Ethylenediaminetetraacetic Acid	72.2 (13)	56.8 (281)	48.2 (159)	73.9 (122)	< 0.001
Hydrogen Peroxide	-	1.6 (8)	1.2 (4)	2.4 (4)	*NS*
Hypochlorous Acid	-	0.4 (2)	0.3 (1)	0.6 (1)	*NS*
Iodine	5.6 (1)	0.4 (2)	-	1.2 (2)	*NS*
Isopropyl Alcohol	-	0.2 (1)	-	0.6 (1)	*NS*
Local Anaesthetic	-	9.1 (45)	10.6 (35)	6.1 (10)	*NS*
Saline	5.6 (1)	6.5 (32)	7.6 (25)	4.2 (7)	*NS*
Sodium Hypochlorite	100.0 (18)	93.7 (464)	92.4 (305)	96.4 (159)	*NS*
Succinic Acid	-	0.2 (1)	0.3 (1)	-	*NS*
Sodium Hypochlorite & Chelating Agent	83.0 (15)	56.2 (278)	48.8 (161)	73.3 (121)	< 0.001

The figures in parenthesis represent the total number of respondents

a – statistically significant difference between NHS and Private GDPs as per the chi-squared test

NS – non significant ($P > 0.01$)

Table 3: Trends in sodium hypochlorite (NaOCl) concentration and contact time usage for primary root canal treatment.

NaOCl	Percentage Response (*n*)				
i) Concentration (%)	**Schools (18)**	**GDPs (495)**	**NHS (330)**	**Private (165)**	***P*** [a]
N/A	-	6.3 (31)	7.6 (25)	3.6 (6)	*NS*
> 0.5 – 1	16.7 (3)	9.9 (49)	12.4 (41)	4.8 (8)	*< 0.01*
> 1 – 2	38.9 (7)	14.9 (74)	16.7 (55)	11.5 (19)	*NS*
> 2 – 3	44.4 (8)	39.6 (196)	39.7 (131)	39.4 (65)	*NS*
> 3 – 4	-	11.5 (57)	10.0 (33)	14.7 (24)	*NS*
> 4 – 5	-	9.3 (46)	7.0 (23)	13.9 (23)	*NS*
> 5 – 6	-	6.3 (31)	3.6 (12)	11.5 (19)	*< 0.01*
Unknown	-	2.2 (11)	3.0 (10)	0.6 (1)	*NS*
ii) Contact Time (min)	**Schools (18)**	**GDPs (495)**	**NHS (330)**	**Private (165)**	***P*** [a]
N/A	-	6.3 (31)	7.6 (25)	3.6 (6)	*NS*
> 0 – 5	5.6 (1)	16.7 (83)	19.4 (64)	11.5 (19)	*NS*
> 5 – 10	22.2 (4)	18.5 (92)	22.1 (73)	11.5 (19)	*< 0.01*
> 10 – 15	11.2 (2)	11.0 (54)	10.5 (35)	11.5 (19)	*NS*
> 15 – 20	5.6 (1)	8.9 (44)	8.8 (29)	9.1 (15)	*NS*
> 20 – 25	-	5.9 (29)	5.8 (19)	6.1 (10)	*NS*
> 25 – 30	-	10.5 (52)	8.8 (29)	13.9 (23)	*NS*
> 30 – 35	5.6 (1)	8.3 (41)	8.2 (27)	8.5 (14)	*NS*
> 35 – 40	11.2 (2)	12.5 (62)	8.2 (27)	21.3 (35)	< 0.0001

Other	38.9 (7)	1.4 (7)	0.6 (2)	3.0 (5)	*NS*

The figures in parenthesis represent the total number of respondents

a – statistically significant difference between NHS and Private GDPs as per the chi-squared test

NS – non significant (*P* > 0.01)

Table 4: Trends in ethylenediaminetetraacetic acid (EDTA) contact time and final rinse protocols usage for primary root canal treatment.

EDTA	**Percentage Response (*n*)**				
i) Contact Time (min)	**Schools (18)**	**GDPs (495)**	**NHS (330)**	**Private (165)**	**P [a]**
N/A	22.2 (4)	43.2 (214)	51.8 (171)	26.1 (43)	*< 0.001*
> 0 – 5	66.7 (12)	39.9 (197)	32.1 (106)	55.2 (91)	*NS*
> 5 – 10	11.1 (2)	10.3 (51)	10.7 (35)	9.6 (16)	*NS*
> 10 – 15	-	2.6 (13)	0.9 (3)	6.1 (10)	*NS*
> 15 – 20	-	1.8 (9)	2.1 (7)	1.2 (2)	*NS*
> 20 – 25	-	0.4 (2)	0.6 (2)	-	*NS*
> 25 – 30	-	1.0 (5)	1.2 (4)	0.6 (1)	*NS*
> 30 – 35	-	0.6 (3)	0.6 (2)	0.6 (1)	*NS*
> 35 – 40	-	0.2 (1)	-	0.6 (1)	*NS*
Other	-	-	-	-	-
ii) Penultimate [P] & Final [F] Rinse Protocol	**Schools (18)**	**GDPs (495)**	**NHS (330)**	**Private (165)**	**P [a]**
N/A	22.2 (4)	43.2 (214)	51.8 (171)	26.1 (43)	*< 0.001*
NaOCl [P] → EDTA [F]	22.2 (4)	11.3 (56)	10.0 (33)	13.9 (23)	*NS*
EDTA [P] → NaOCl [F]	55.6 (10)	45.5 (225)	38.2 (126)	60.0 (99)	*NS*

The figures in parenthesis represent the total number of respondents

a – statistically significant difference between NHS and Private GDPs as per the chi-squared test

NS – non significant ($P > 0.01$)

Table 5: Trends in irrigant agitation for primary root canal treatment (multiple responses were allowed for the various techniques)

Irrigant Agitation	**Percentage Response (*n*)**				
i) Techniques	**Schools (18)**	**GDPs (495)**	**NHS (330)**	**Private (165)**	***P*** [a]
N/A	27.8 (5)	40.2 (199)	49.1 (162)	22.4 (37)	*< 0.001*
Manual Dynamic Activation	72.2 (13)	44.8 (222)	140.0 (132)	54.5 (90)	*NS*
Passive Ultrasonic	16.7 (3)	20.0 (99)	15.2 (50)	29.7 (49)	*NS*
Sonic Irrigation	16.7 (3)	7.3 (36)	3.94 (13)	13.9 (23)	*< 0.01*
Apical Negative Pressure	-	1.8 (9)	1.2 (4)	3.0 (5)	*NS*
Canal Brush	-	0.2 (1)	0.3 (1)	-	*NS*
ii) Duration (sec)	**Schools (18)**	**GDPs (495)**	**NHS (330)**	**Private (165)**	***P*** [a]
N/A	27.8 (5)	40.2 (199)	49.1 (162)	22.4 (37)	*< 0.001*
> 0 – 30	27.8 (5)	22.2 (110)	21.5 (71)	23.6 (39)	*NS*
> 30 – 60	22.2 (4)	21.2 (105)	18.2 (60)	27.3 (45)	*NS*
> 60 – 90	11.1 (2)	8.7 (43)	5.5 (18)	15.2 (25)	*NS*
> 90 – 120	-	5.5 (27)	4.5 (15)	7.3 (12)	*NS*
> 120 – 150	-	0.6 (3)	0.3 (1)	1.2 (2)	*NS*
> 150 – 180	11.1 (2)	1.6 (8)	0.9 (3)	3.1 (5)	*NS*

Other	-	-	-	-	-

The figures in parenthesis represent the total number of respondents

a – statistically significant difference between NHS and Private GDPs as per the chi-squared test

NS – non significant ($P > 0.01$)

Supplementary 1: Sample questionnaire distributed to endodontic course leads in UK & Ireland dental schools

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Q1 Which of the following irrigants do you teach undergraduate students to use during primary root canal treatment? (Please note you may choose more than one option)

- Chlorhexidine
- Citric Acid
- Dual Rinse HEDP
- Ethylenediaminetetraacetic acid (EDTA)
- Hydrogen Peroxide
- Iodine
- Local Anaesthetic
- Saline
- Sodium Hypochlorite (NaOCl)
- Other (please specify)

Q2 If NaOCl was selected, please could you specify the concentration that you teach undergraduate students to use during primary root canal treatment?

- N/A (do not use NaOCl)
- 0.5 – 1.0%
- 1.1 – 2.0%
- 2.1 – 3.0%
- 3.1 – 4.0%
- 4.1 – 5.0%
- 5.1 – 6.0%
- Other (please specify)

Q3 If NaOCl was selected, please could you specify the average time period in minutes that you teach undergraduate students to use this irrigant for during primary root canal treatment:

Q6 Do you teach undergraduate students to routinely heat the irrigants during primary root canal treatment?

- Yes
- No
- Other (please specify)

Q7 Which of the following irrigant activation techniques do you teach undergraduate students to use during primary root canal treatment?
(Please note you may choose more than one option)

- N/A (do not agitate irrigants)
- Apical Negative Pressure (e.g. EndoVac)
- Manual Dynamic Activation (GP Pumping)
- Passive Ultrasonic Irrigation
- Sonic Irrigation (e.g. EndoActivaor)
- Other (please specify)

Q8 If you teach undergraduate students to routinely use irrigant activation techniques during primary root canal treatment, please could you specify the recommended duration in seconds per canal?

- N/A (do not use NaOCl)
- > 0 – 5
- > 5 – 10
- > 10 – 15
- > 15 – 20
- > 20 – 25
- > 25 – 30
- > 35 – 40
- Other (please specify)

Q4 If EDTA was selected, please could you specify the average time period that you teach undergraduate students to use this irrigant for during primary root canal treatment?

- N/A (do not use EDTA)
- > 0 – 5
- > 5 – 10
- > 10 – 15
- > 15 – 20
- > 20 – 25
- > 25 – 30
- > 35 – 40
- Other (please specify)

Q5 If both NaOCl and EDTA were selected, what penultimate & final rinse sequence do you teach undergraduate students to use during primary root canal treatment?

- N/A (do not use NaOCl and/or EDTA)
- NaOCl penultimate and EDTA final
- EDTA penultimate and NaOCl final
- Other (please specify)

- N/A (do not agitate irrigants)
- > 0 – 30
- > 30 – 60
- > 60 – 90
- > 90 – 120
- > 120 – 150
- > 150 – 180
- Other (please specify)

Q9 Please could you specify a reason for selecting your irrigant choice in Q1?

Q10 Do you have any further comments or information you would like to add?

Supplementary 2: Sample questionnaire distributed to GDPs in the UK

Q1 Did you attain your primary qualification from a dental institute within the UK or Ireland?

- Yes
- No

Q9 If EDTA was selected, please could you specify the average time period that you use this irrigant for during primary root canal treatment?

- N/A (do not use EDTA)

Q2 If selecting yes to Q1, please can you state the dental school you attained your primary qualification from?

Q3 How many years have you practiced as a general dentist within the UK?

Q4 Which country do you predominately practice in?

- England
- Northern Ireland
- Scotland
- Wales

Q5 Approximately what proportion of your practice would you deem private?

- 0 – 50 %
- 51 – 100%

Q6 Which of the following irrigants do you use during primary root canal treatment? (Please note you may choose more than one option)

- Chlorhexidine
- Citric Acid
- Dual Rinse HEDP
- Ethylenediaminetetraacetic acid (EDTA)
- Hydrogen Peroxide
- Iodine
- Local Anaesthetic
- Saline
- Sodium Hypochlorite (NaOCl)
- Other (please specify)

Q If NaOCl was selected, please could

- > 0 – 5
- > 5 – 10
- > 10 – 15
- > 15 – 20
- > 20 – 25
- > 25 – 30
- > 35 – 40
- Other (please specify)

Q10 If both NaOCl and EDTA were selected, what penultimate & final rinse sequence do use during primary root canal treatment?

- N/A (do not use NaOCl and/or EDTA)
- NaOCl penultimate and EDTA final
- EDTA penultimate and NaOCl final
- Other (please specify)

Q11 Do you routinely heat the irrigants during primary root canal treatment?

- Yes
- No
- Other (please specify)

Q12 Which of the following irrigant activation techniques do you to use during primary root canal treatment? (Please note you may choose more than one option)

- N/A (do not agitate irrigants)
- Apical Negative Pressure (e.g. EndoVac)
- Manual Dynamic Activation (GP Pumping)
- Passive Ultrasonic Irrigation

7 you specify the concentration that you routinely use during root canal treatment?

- N/A (do not use NaOCl)
- 0.5 – 1.0%
- 1.1 – 2.0%
- 2.1 – 3.0%
- 3.1 – 4.0%
- 4.1 – 5.0%
- 5.1 – 6.0%
- Other (please specify)

Q8 If NaOCl was selected, please could you specify the average time period in minutes that you use this irrigant for during primary root canal treatment:

- N/A (do not use NaOCl)
- > 0 – 5
- > 5 – 10
- > 10 – 15
- > 15 – 20
- > 20 – 25
- > 25 – 30
- > 35 – 40
- Other (please specify)
- Sonic Irrigation (e.g. EndoActivaor)
- Other (please specify

Q13 If you routinely use irrigant activation techniques during primary root canal treatment, please could you specify the duration in seconds per canal?

- N/A (do not agitate irrigants)
- > 0 – 30
- > 30 – 60
- > 60 – 90
- > 90 – 120
- > 120 – 150
- > 150 – 180
- Other (please specify)

Q14 Please could you specify a reason for selecting your irrigant choice in Q5?

Q15 Do you have any further comments or information you would like to add?